2008 ASME Pressure Vessel & Piping Conference
Chicago, IL

Practical Application Of Fastener Preload Guidance Research

John Ludman- E.I. DuPont

Jerry Waterland- Virginia Sealing Products, Inc.

July 29, 2008

What Torque To Use?

NPS 8 x 600, 304/FG SW, 1-1/8” B7 Bolts (lubricated), 400 psig, Ambient Temp

750 ft-lb: ASME PCC-1
307 ft-lb: Gasket Minimum
710 ft-lb: Gasket & Bolt
395 ft-lb: T3 Gasket Tightness
978 ft-lb: Simultaneous Component Analysis (PVRC 07-BFC-01)

Current Methods For Determining Assembly Preload (Torque)

1. Percent Of Bolt Yield
   - Ex. ASME PCC-1 (50 ksi)
   - Turbine Contractors/OEMs (45-60 ksi)
2. Gasket Requirements
   - Minimum Stress To Seal
   - Maximum Compressive Stress
3. Gasket Min & Bolt Max
   - Minimum Stress To Seal (Gasket)
   - Maximum Compressive Stress (Gasket)
   - Maximum % Bolt Yield
4. Gasket Tightness (Tp)
   - Ex: T3 seal
5. System Component Analysis
   - Ex. PVRC 07-BFC-01

Limitations Of Current Methods

1. Non-Optimum Gasket Stress

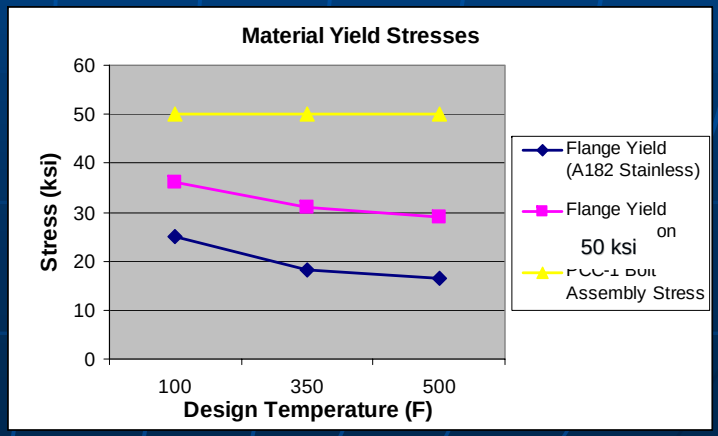
   Methods #1, #4

2. Potential For Flange or Other System Component Damage

   Methods #1, #2, #3, #4

3. No Consideration For Thermal Effects On Joint

   Methods #1, #2, #3, #4



ASME PCC-1 Table 1 Caveats

"Individually select the Target Prestress for each joint, considering each joint element that will be affected by the prestress"

"…50 ksi root area pre-stress level is generally considered suitable for joint systems designed using SA193-B7 low alloy steel bolts…"

Be Aware:

ASME B16.5 flanges were not designed following ASME Section V111 Appendix 2 rules

Table 1 Caveats Are Not Well Known:

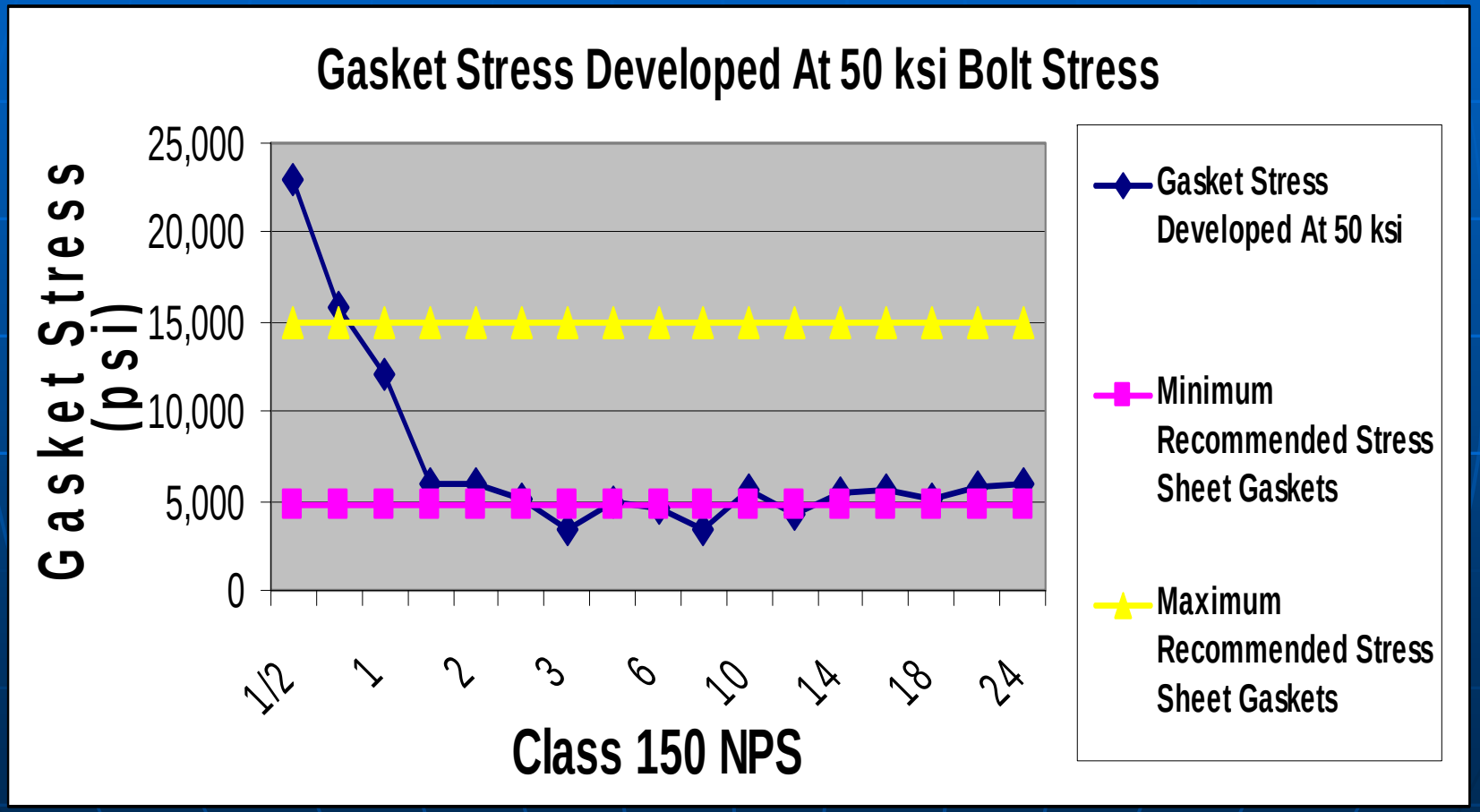
April 8, 2008 revision of a large worldwide chemical manufacturing company's Corporate Bolted Joint Assembly & Inspection Procedure

6.8.7.3 Torque Application

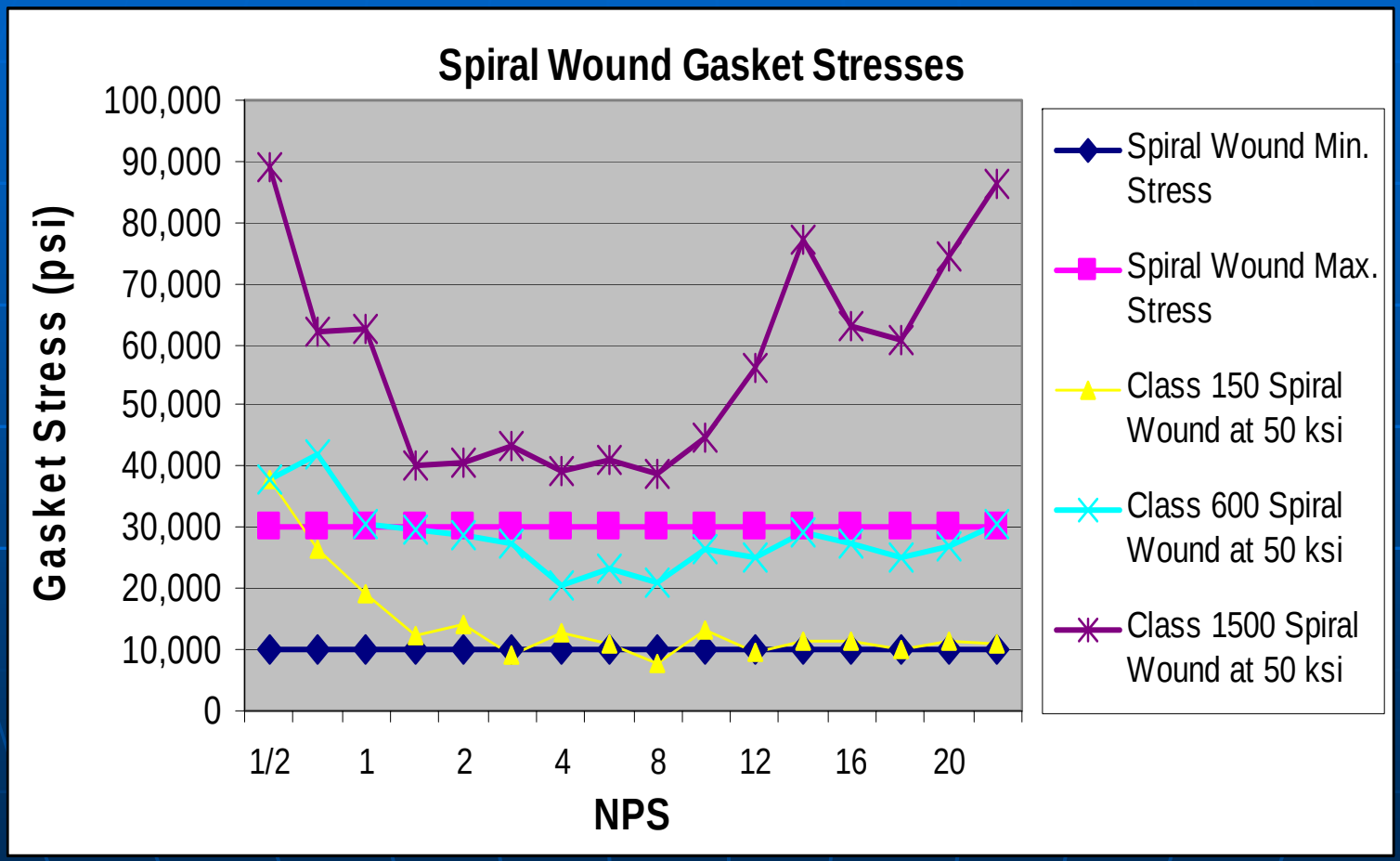
NOTE: Torque values are based on achieving a bolt stress level of 50% of the yield strength of B7 and Class 2 B8/B8M bolting material (coating nut factor of .15)

DETERMINE **the correct torque values in accordance with the torque values in the respective torque table (Attachments 5 through 9 if applicable).**

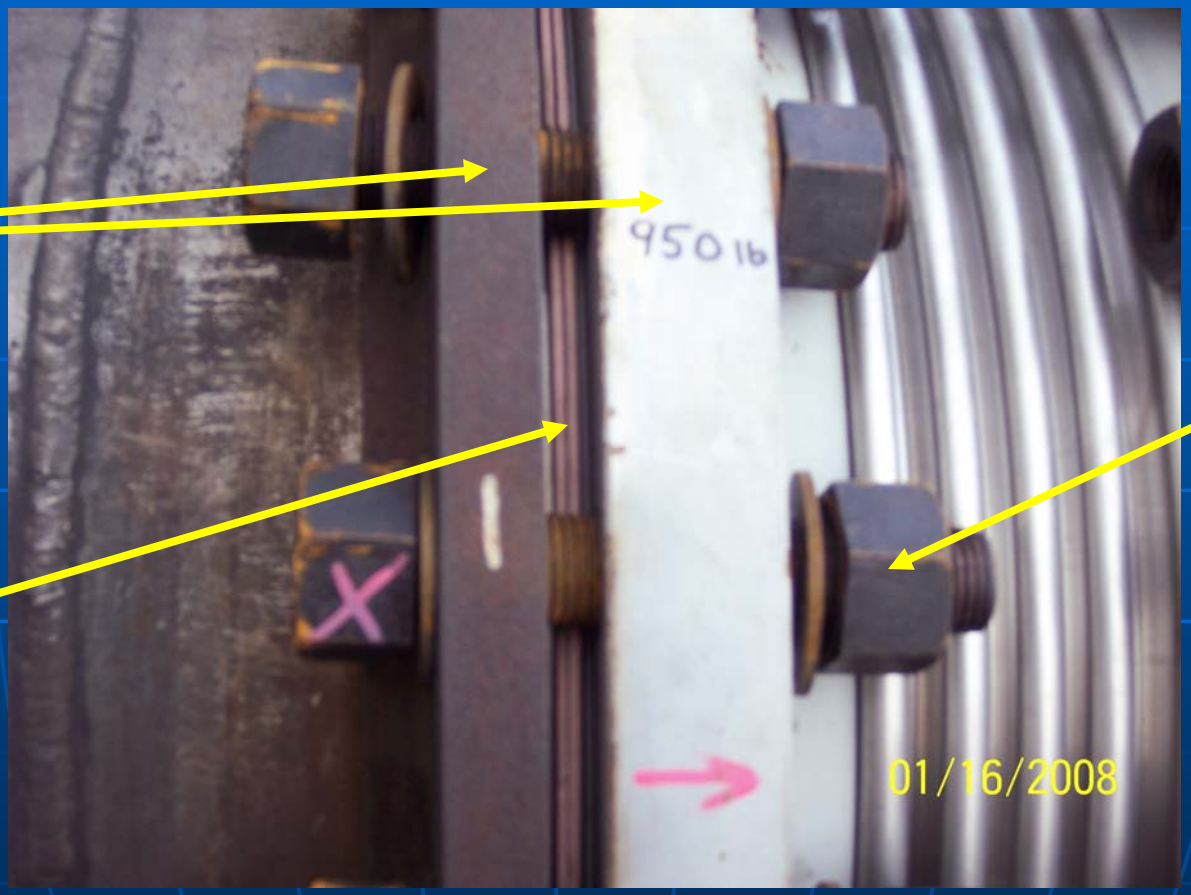
Non-Optimum Stress Developed On Sheet Type Gaskets



Non-Optimum Stress Developed On Many Spiral Wound Type Gaskets at 50 ksi Bolt Prestress



Alternative Approach:
Evaluate Simultaneous System Component Limits



PVRC Project 07-BFC-01
Principal Investigator: Randy Wacker, E.I. DuPont
Flange Assembly Preload Guidance

Scope

- *Materials and Geometry*

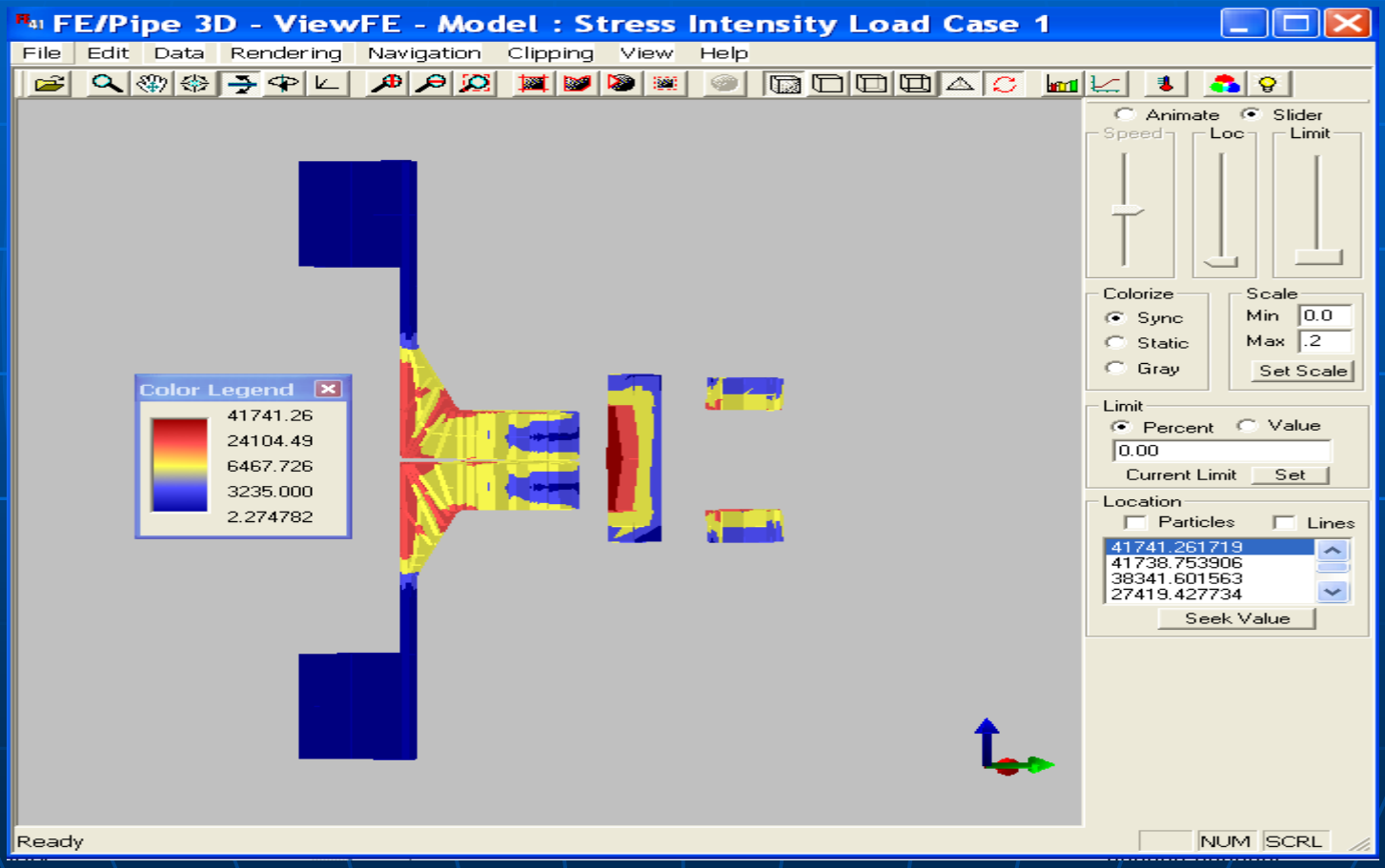
  * Flange Material - A105 and A182 Grade L
  * Flange Class - 150, 300 & 600
  * Flanges Sizes - ½” to 24” (16 diameters)
  * Fasteners - A193 Grade B7
  * Two Gaskets - SWG & ePTFE
  * Three Design Conditions- 100F, 350F, 500F

(all combinations analyzed)

2 Flange Metallurgies x 2 Gasket Types x 16 Flange Sizes x 3 Design Conditions

Sampling of FEA Program/Output

3D Stress with Full Load - Graphic



Master Data Sheets

Variation in Which Component Limit Is Reached:

Different Gasket Type, CS vs. SS Flange

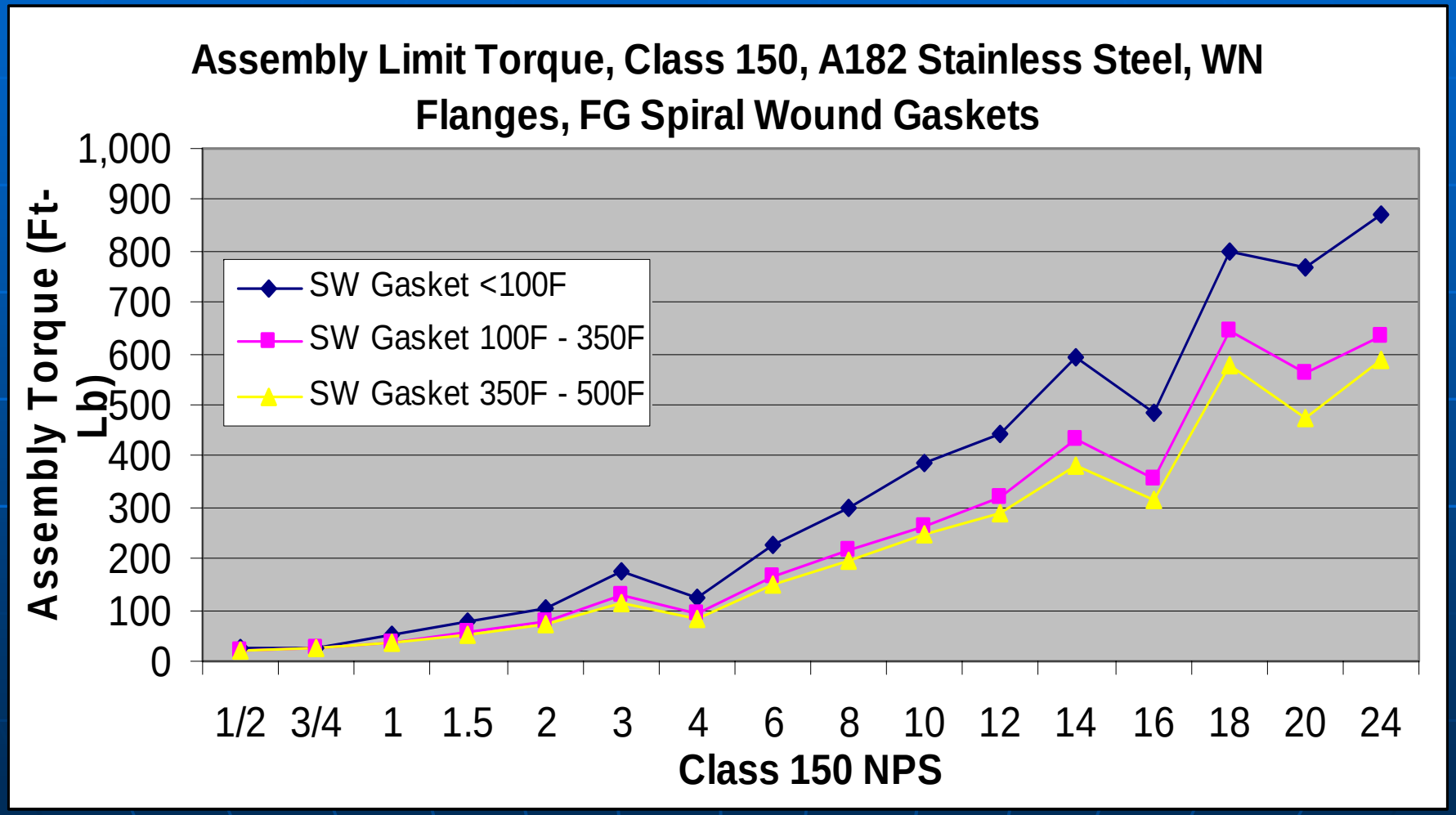
Carbon Steel Flange, Spiral Wound Gasket

Lip, in.	0.064	0.088	0.101	0.258	0.342	0.466	0.487	0.561	0.603	0.646	0.688	0.688	0.813	0.906	0.938	1.063
Bearing, in	0.314	0.370	0.413	0.570	0.654	0.841	0.925	1.093	1.197	1.240	1.375	1.375	1.625	1.937	1.969	2.188
Pre Load, lbf	28195	33330	44913	70650	88172	150375	200775	296700	389690	540000	657100	653023	760500	960500	964800	1100000
Hub Stress. psi	45007	45126	46466	44261	39522	41415	46666	52153	52232	54964	55387	55248	55723	52564	52606	54772
Flange Stress, psi	46490	42181	44749	52516	47187	45861	44732	43392	41180	35970	36437	31050	27681	28687	25158	22962
Bolt Stress, Nom+Bending	86694	78580	89942	101058	84928	91274	105331	104511	104462	91623	93938	78710	75978	76465	73026	67055
Bolt Stress, Nom	55942	41253	55585	58485	54561	62241	83102	81870	77503	61252	56421	44850	40931	43079	43272	32621
Gasket Stress (max), psi	30053	29920	29979	30019	30115	30039	27826	24362	22804	25581	23396	20739	18472	17834	15990	14322
Gasket Stress (ave), psi	35899	29409	29279	29523	29326	29175	26865	23031	21358	24314	21634	19745	17086	15035	13712	12028
Flange Rot, deg	0.122	0.127	0.136	0.162	0.175	0.186	0.198	0.24	0.255	0.271	0.29	0.273	0.262	0.268	0.262	0.269
Lift Off?, Y/N																

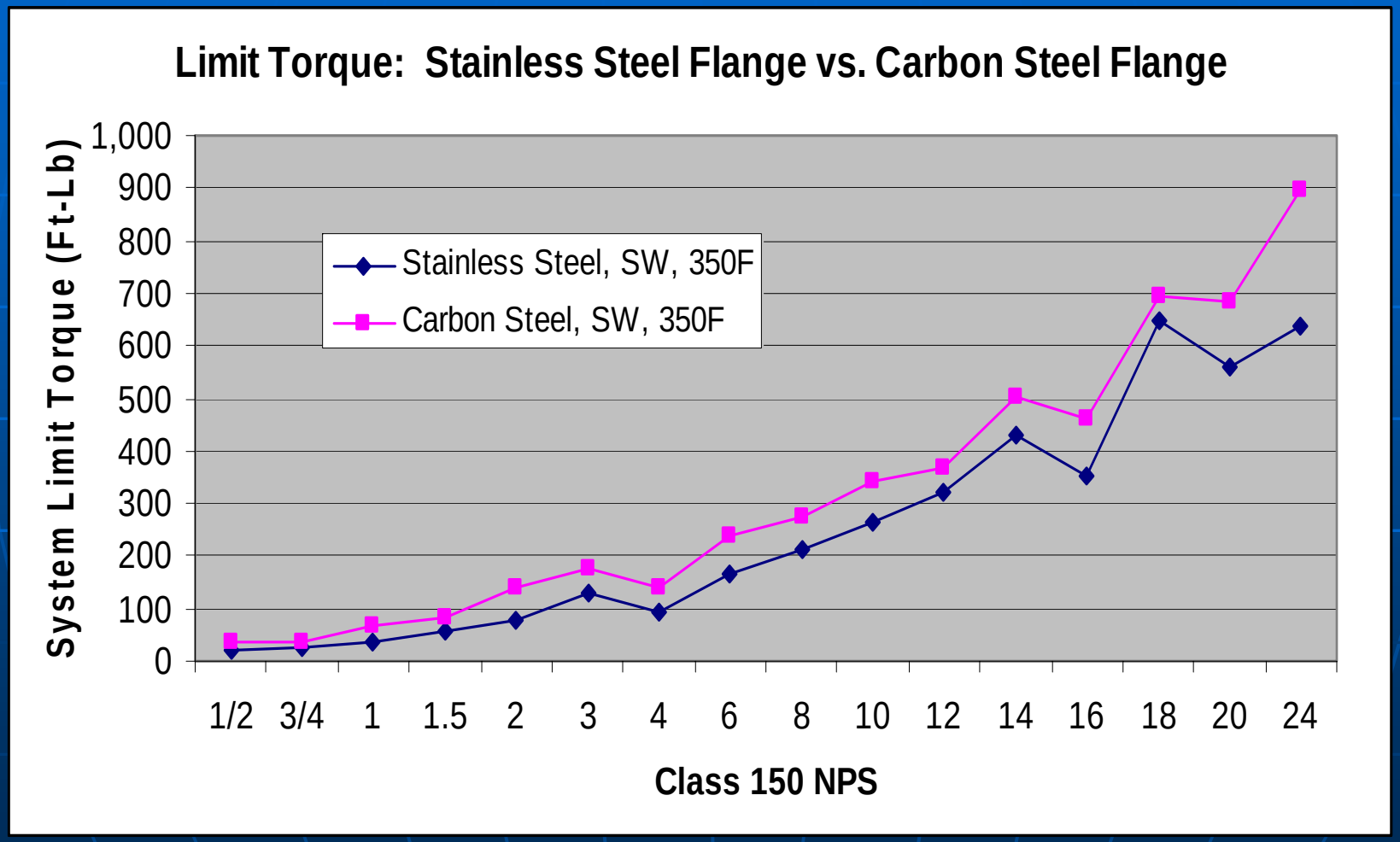
Stainless Steel Flange, PTFE Sheet Gasket

Nominal Pipe Size	1/2	3/4	1	1.5	2	3	4	6	8	10	12	14	16	18	20	24
Lip, in.	0.109	0.118	0.131	0.150	0.157	0.216	0.237	0.278	0.320	0.365	0.375	0.375	0.375	0.375	0.375	0.375
Bearing, in	0.379	0.433	0.476	0.635	0.777	0.966	1.082	1.218	1.320	1.365	1.500	1.500	1.625	1.875	1.875	2.000
Pre Load, lbf	13800	20000	26000	46636	57665	78425	122579	185000	200000	317050	350000	410000	500000	703900	765300	897300
Hub Stress. psi	29,643	33,366	30,500	36,515	35,388	27,714	32,972	29,433	24,556	32,020	30,310	32,459	37,600	32,698	40,597	43,060
Flange Stress, psi	36,456	41,143	39,585	53,511	49,197	40,717	42,157	43,000	34,976	35,133	32,429	32,742	31,405	30,894	30,749	26,286
Bolt Stress, Nom+Bending	60,545	72,949	78,633	108,741	103,506	105,079	102,112	108,975	101,966	102,011	104,857	101,981	101,409	104,118	96,324	95,434
Bolt Stress, Nom	27,380	39,682	51,587	91,895	71,367	97,060	75,853	76,572	82,781	63,056	69,610	62,008	56,710	60,398	51,465	46,067
Gasket Stress (max), psi	15,144	15,306	15,015	13,529	10,835	8,376	12,264	11,690	9,241	13,140	11,922	12,835	13,880	14,873	15,787	15,373
Gasket Stress (ave), psi	14,657	14,698	14,495	12,780	9,868	7,832	8,639	8,287	6,618	8,589	7,137	7,670	7,381	7,660	7,554	6,859
Flange Rot. Boltup, deg	0.096	0.112	0.108	0.16	0.149	0.118	0.2	0.197	0.167	0.233	0.23	0.245	0.282	0.262	0.297	0.319
Torque, ft-lbf	29	42	54	96	150	204	160	289	312	385	425	569	521	824	702	892
Lift Off?, Y/N															y	y

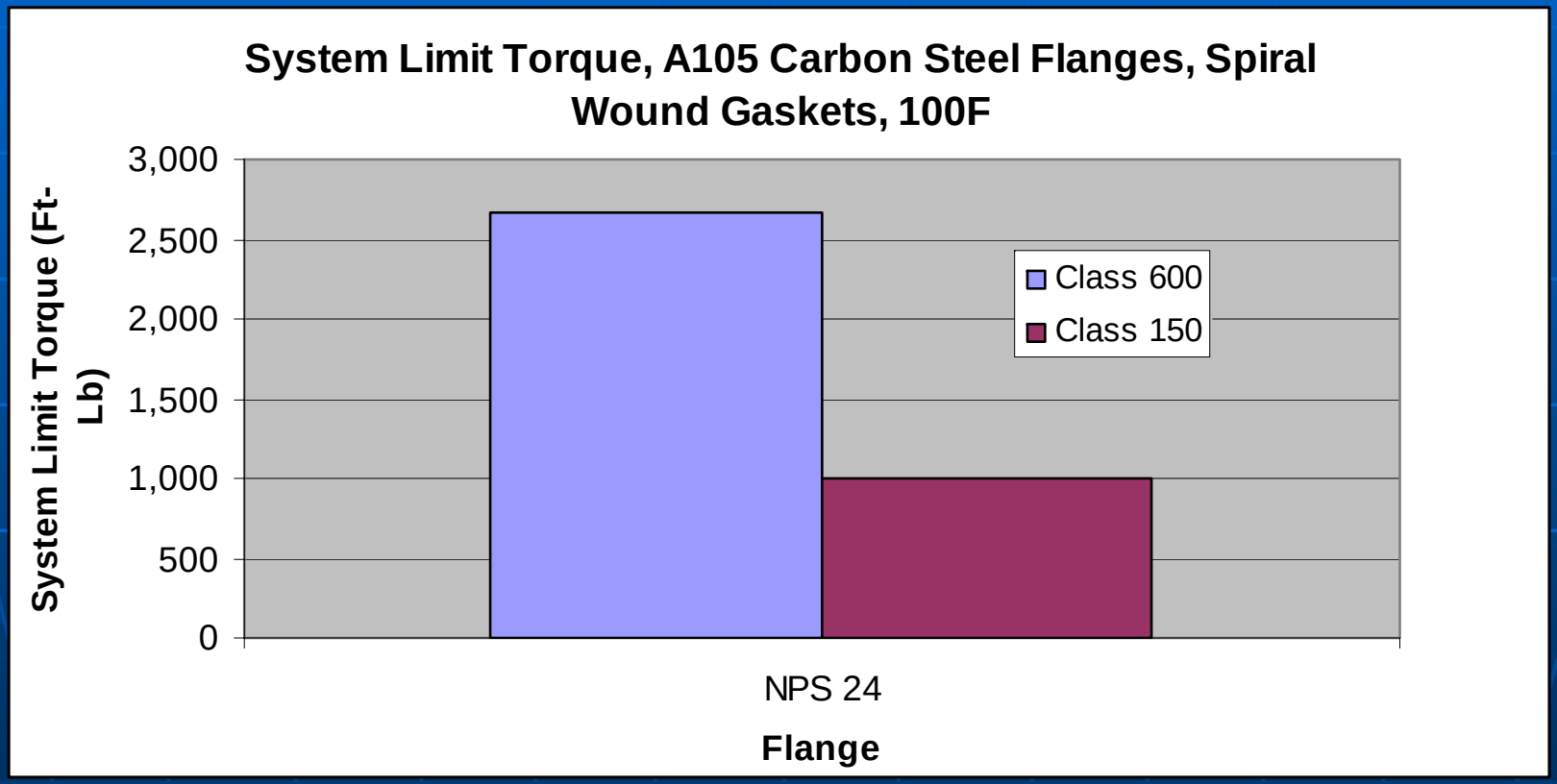
Analysis: Torque Guidance @ Different Operating Temperatures



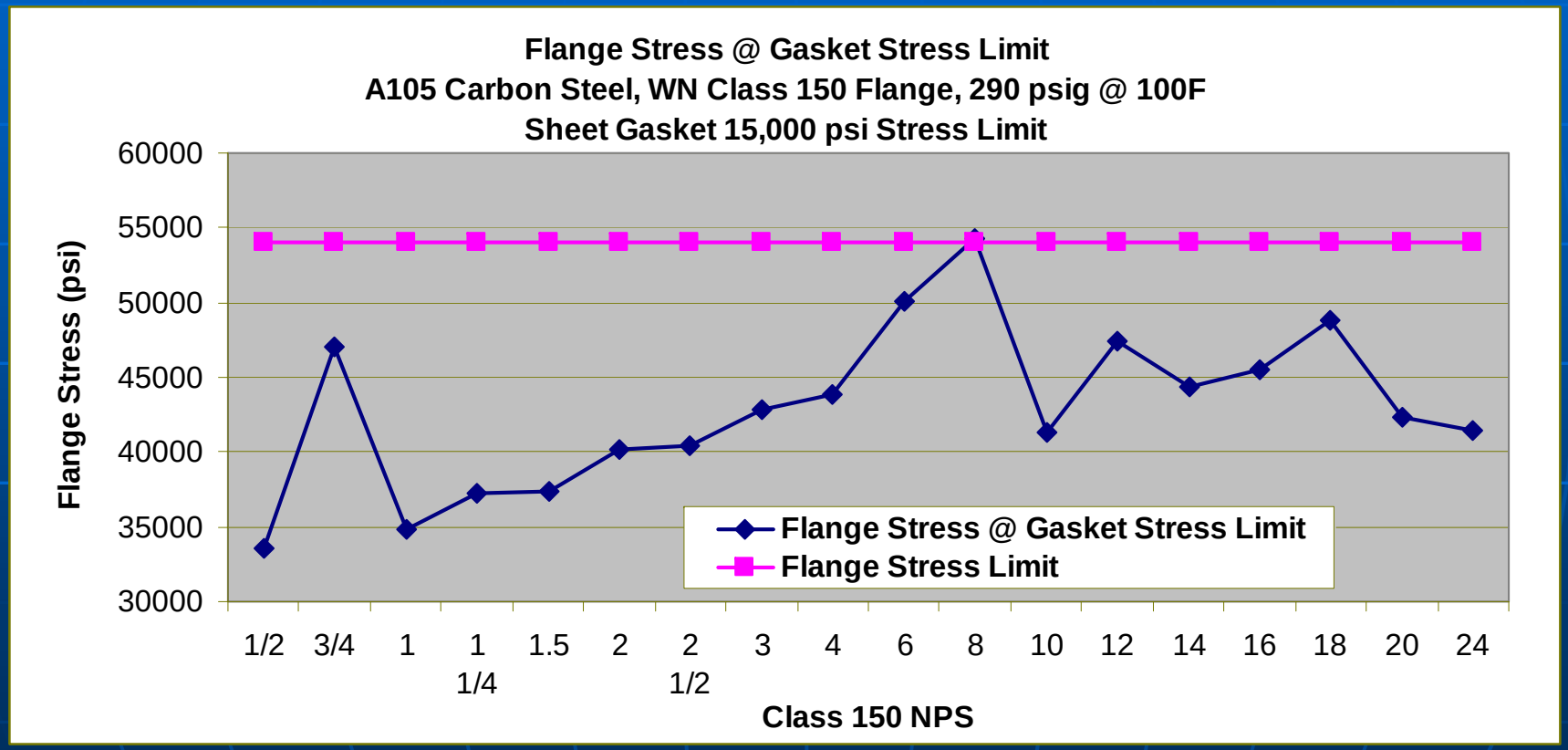
Analysis: Torque Guidance For Different Flange Metallurgy



Analysis: Torque Guidance For Different Flange Pressure Classes



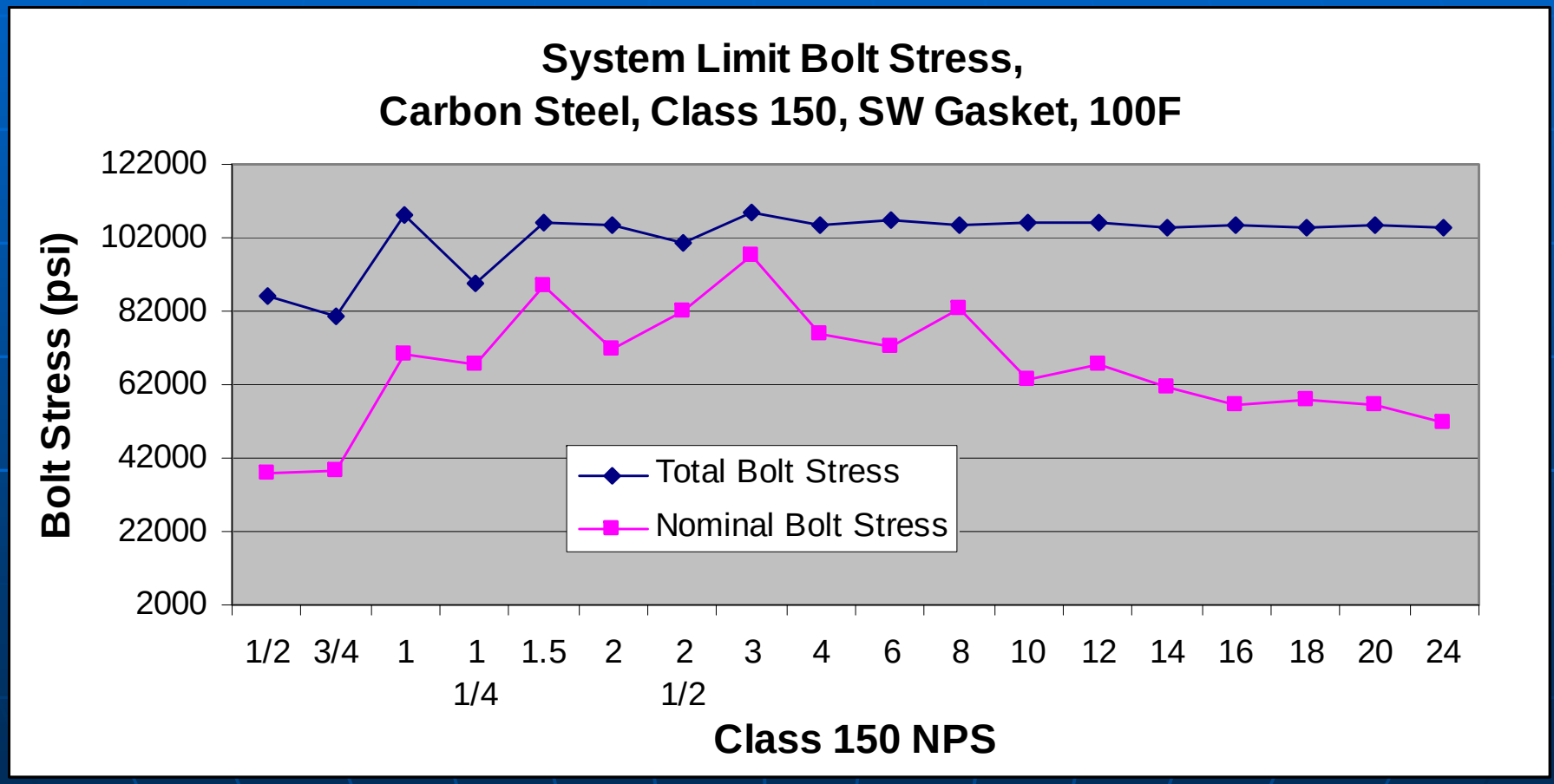
Analysis: Evaluate Component Stress At System Limit- Example: PTFE Sheet Gasket, Class 150 @ 100F



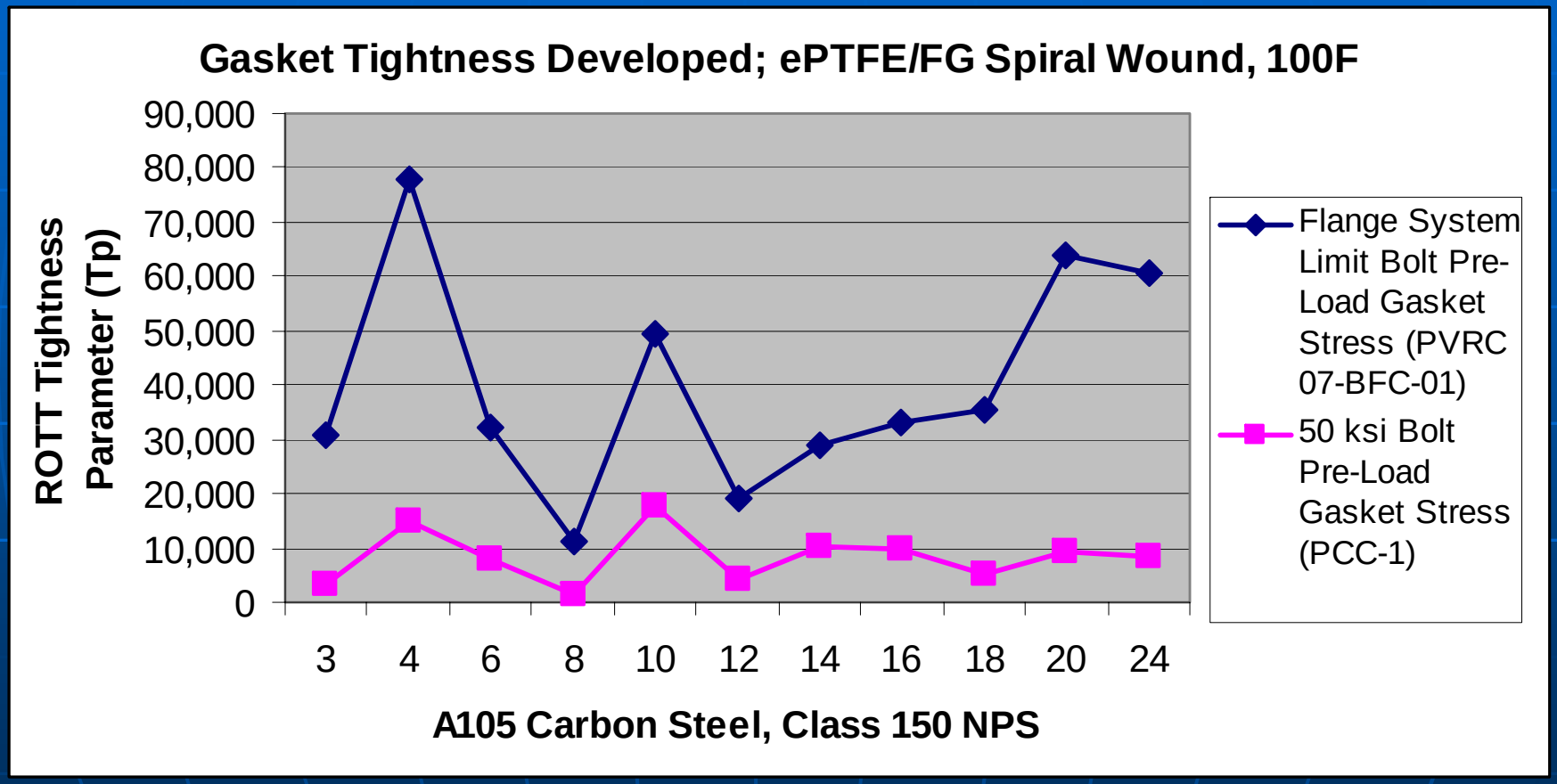
Opportunity For Higher Assembly Bolt Load If Stronger Gasket Is Employed: NPS ½ -4 and NPS 10 - 24

Analysis: Understand Basis For Yield As The Bolt Component Limit

Example: SW Gasket, Class 150 @ 100F



Analysis: Identify Opportunities For Improving Joint Tightness



Opportunity For Significantly Higher Joint Tightness Except NPS 8 and NPS 12

Summary Of User Benefits:

1. Knowledge based assembly torque guidance
2. Reduced likelihood of damaged flanges
3. Greater Tightness Performance
4. Greater margin against gasket relaxation